Renewable energy target and strategy in Denmark

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Renewable energy target and strategy in Denmark

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Department of Wind Energy

Content

- DTU Wind Energy Department
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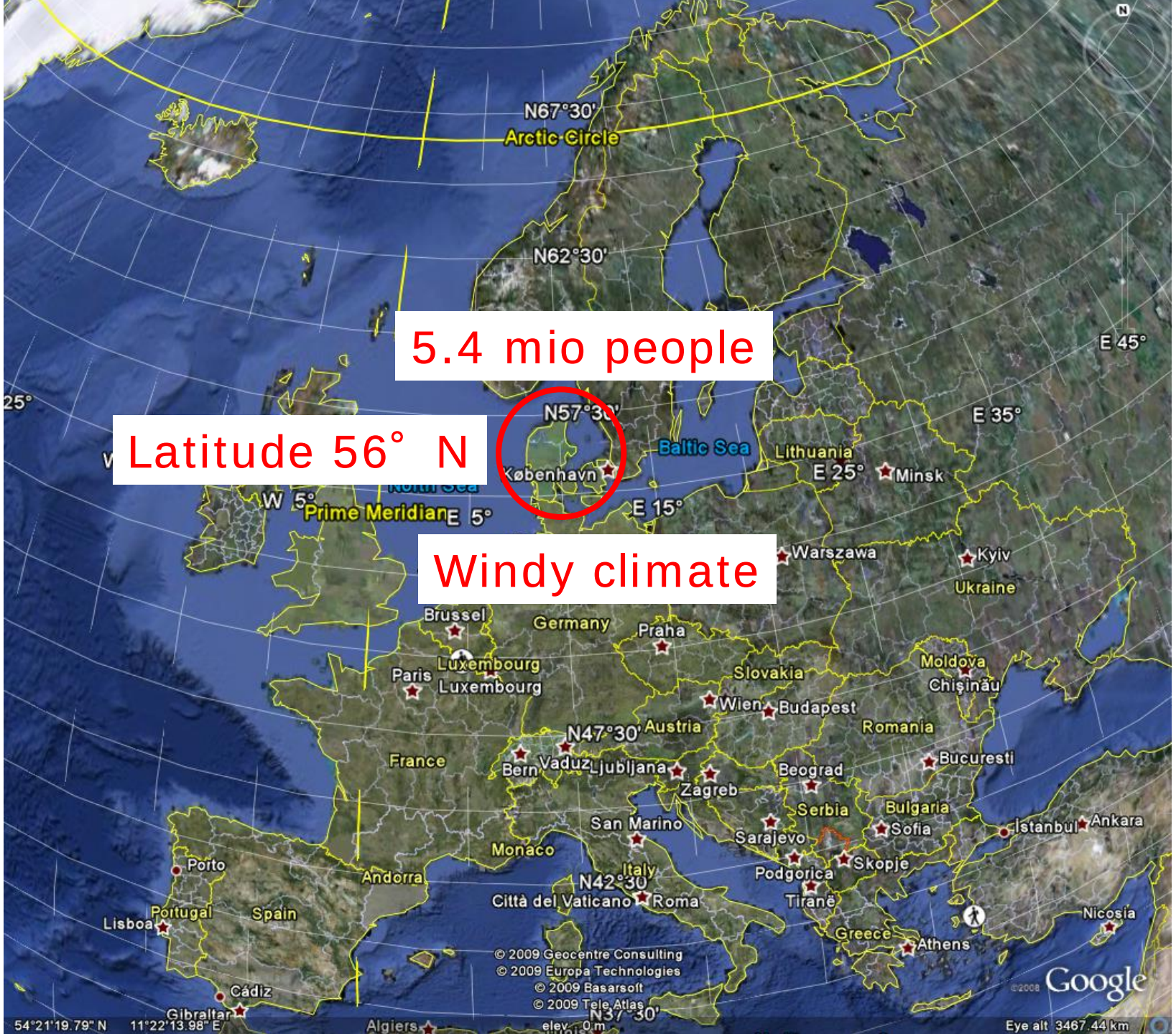
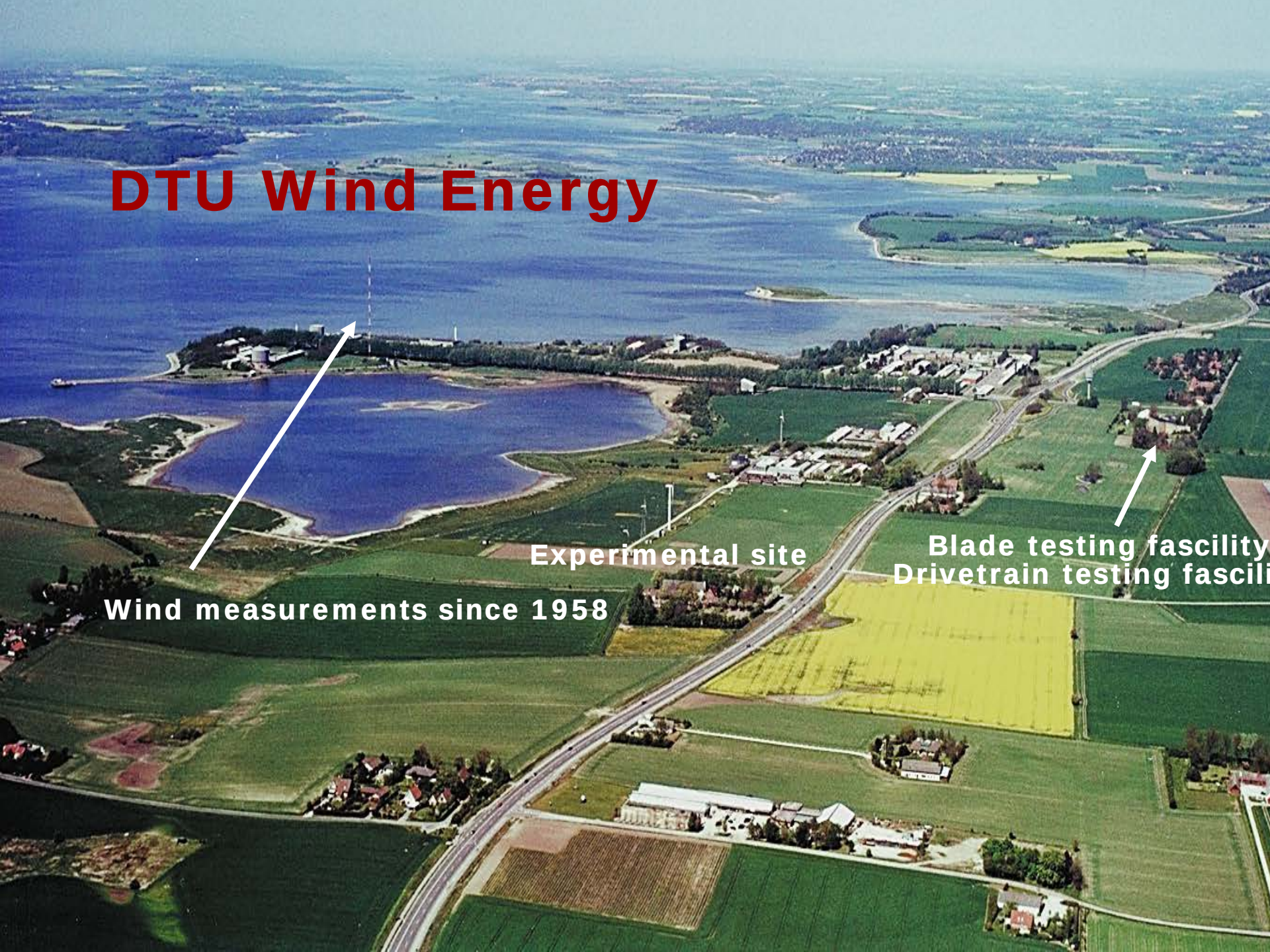
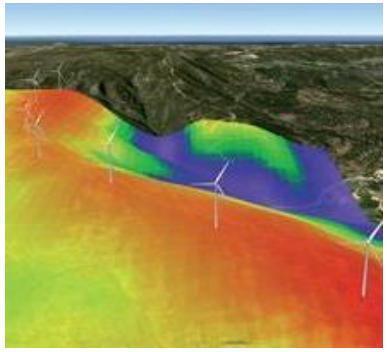

5.4 mio people
Latitude 56° N
Windy climate
N67°30'
Arctic Circle
N62°30'
N57°30'
Baltic Sea
København
Lithuania
Minsk
E 45°
E 35°
E 25°
E 15°
E 5°
W 5°
Prime Meridian
Warszawa
Kyiv
Ukraine
Brussel
Germany
Praha
Luxembourg
Paris
Slovakia
Moldova
Chişinău
Wien
Budapest
Romania
N47°30'
Austria
France
Bern
Vaduz
Ljubljana
Zagreb
Beograd
Bucuresti
Serbia
Bulgaria
San Marino
Sarajevo
Sofia
Istanbul
Ankara
Monaco
Porto
Andorra
Italy
Skopje
Podgorica
N42°30'
Città del Vaticano
Roma
Tiranë
Portugal
Spain
Lisboa
Nicosia
Greece
Athens
Cádiz
Gibraltar
Algiers
© 2009 Geocentre Consulting
© 2009 Europa Technologies
© 2009 Basarsoft
© 2009 Tele Atlas
Google
54°21'19.79" N 11°22'13.98" E
elev -0 m
Eye alt 3467.44 km


DTU Wind Energy
Wind measurements since 1958
Experimental site
Blade testing fascility
Drivetrain testing fascili

DTU Wind Energy

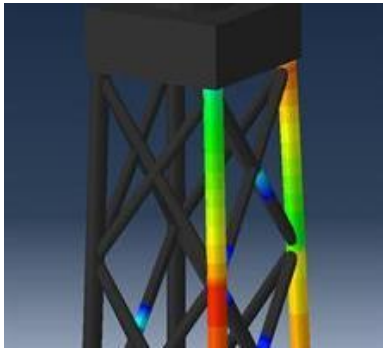
> 250 staff members
Including 150 academic staff members and 50 PhD students



Meteorology

Wind Energy Systems

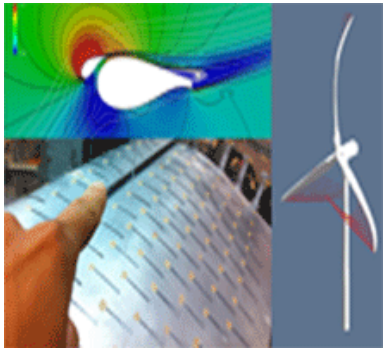
Test and Measurements



Wind Turbines

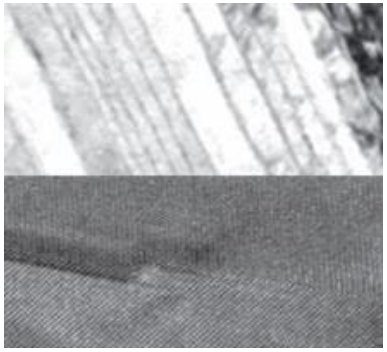
http://www.vindenergi.dtu.dk

Fluid Mechanics



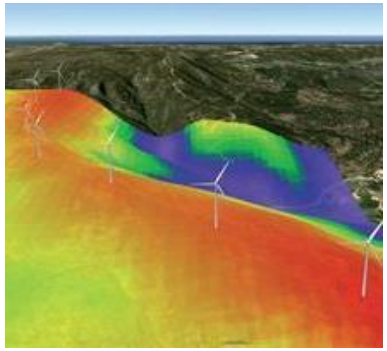
Aeroelastic design

Composite and Materials Mechanics



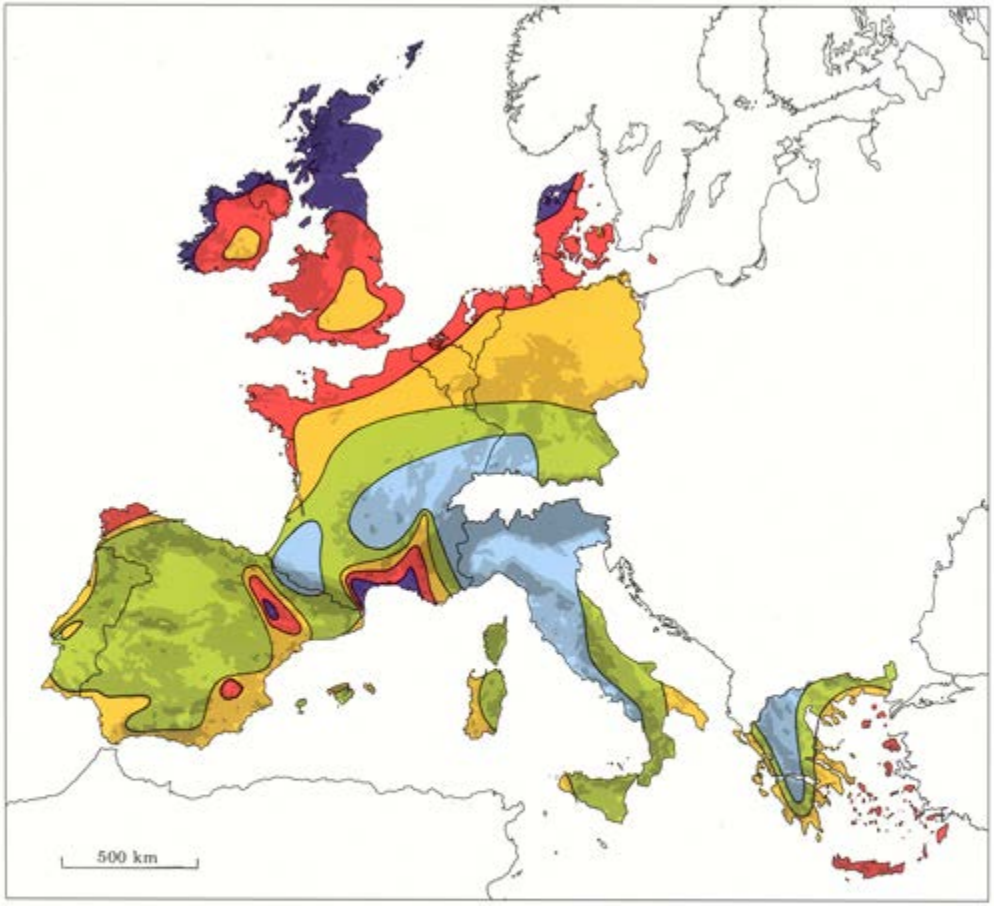
Materials Science and Characterisation

DTU Wind Energy



Meteorology

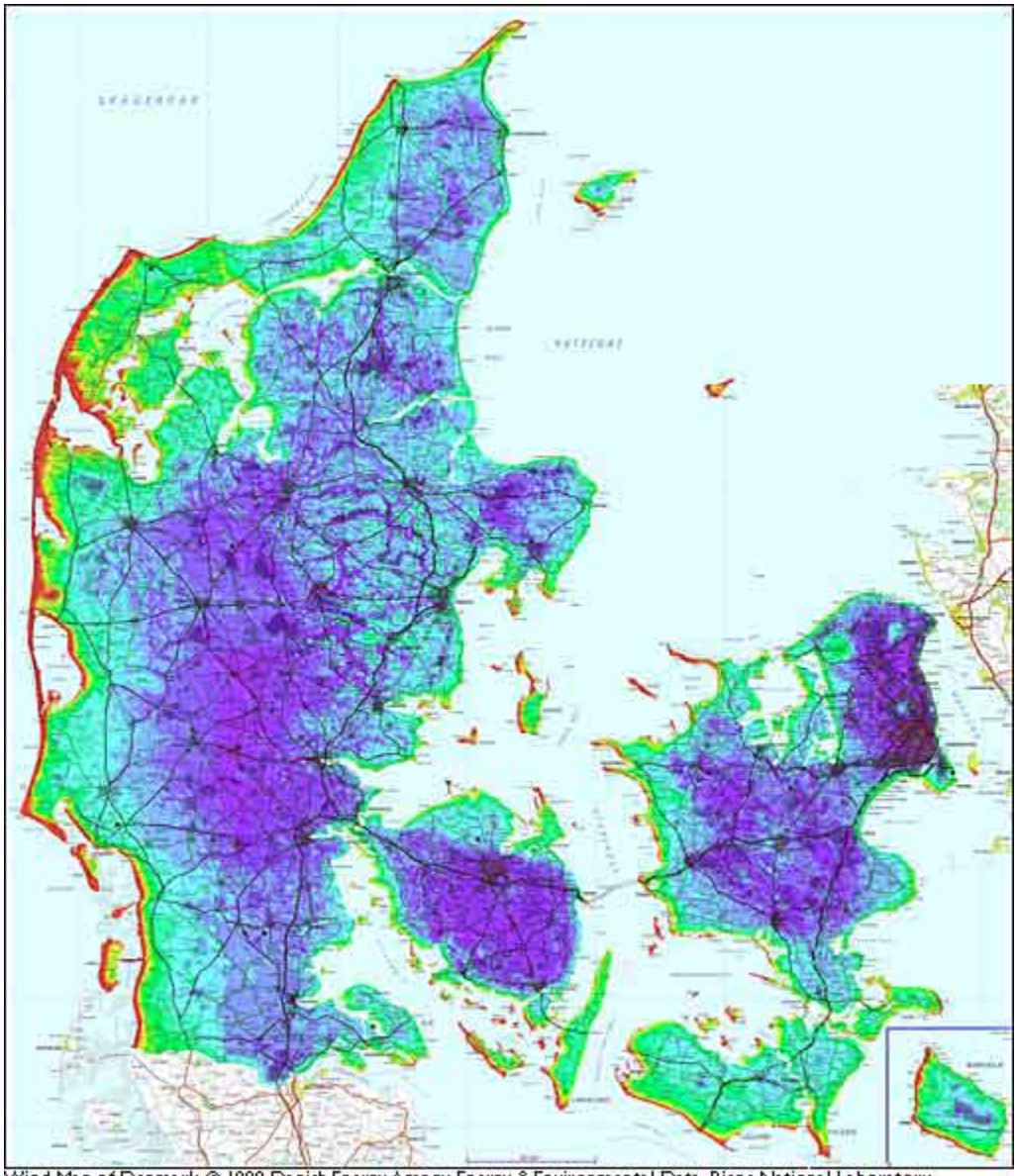
European Wind Atlas 1989



Wind resources[1] at 50 metres above ground level for five different topographic conditions

	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Wind resource map of Denmark 1999



Wind Map of Denmark © 1999 Danish Energy Agency, Energy & Environmental Data, Risoe National Laboratory

Global wind atlas 2015

- Released at IRENA global atlas web-site October 2015
- Freely available wind energy statistics

New European Wind Atlas (2015-2020)

- NEWA will provide a unified high resolution and freely available data-set of wind energy resource in Europe with a resolution 20-30 meters in at least 10 wind turbine relevant heights.

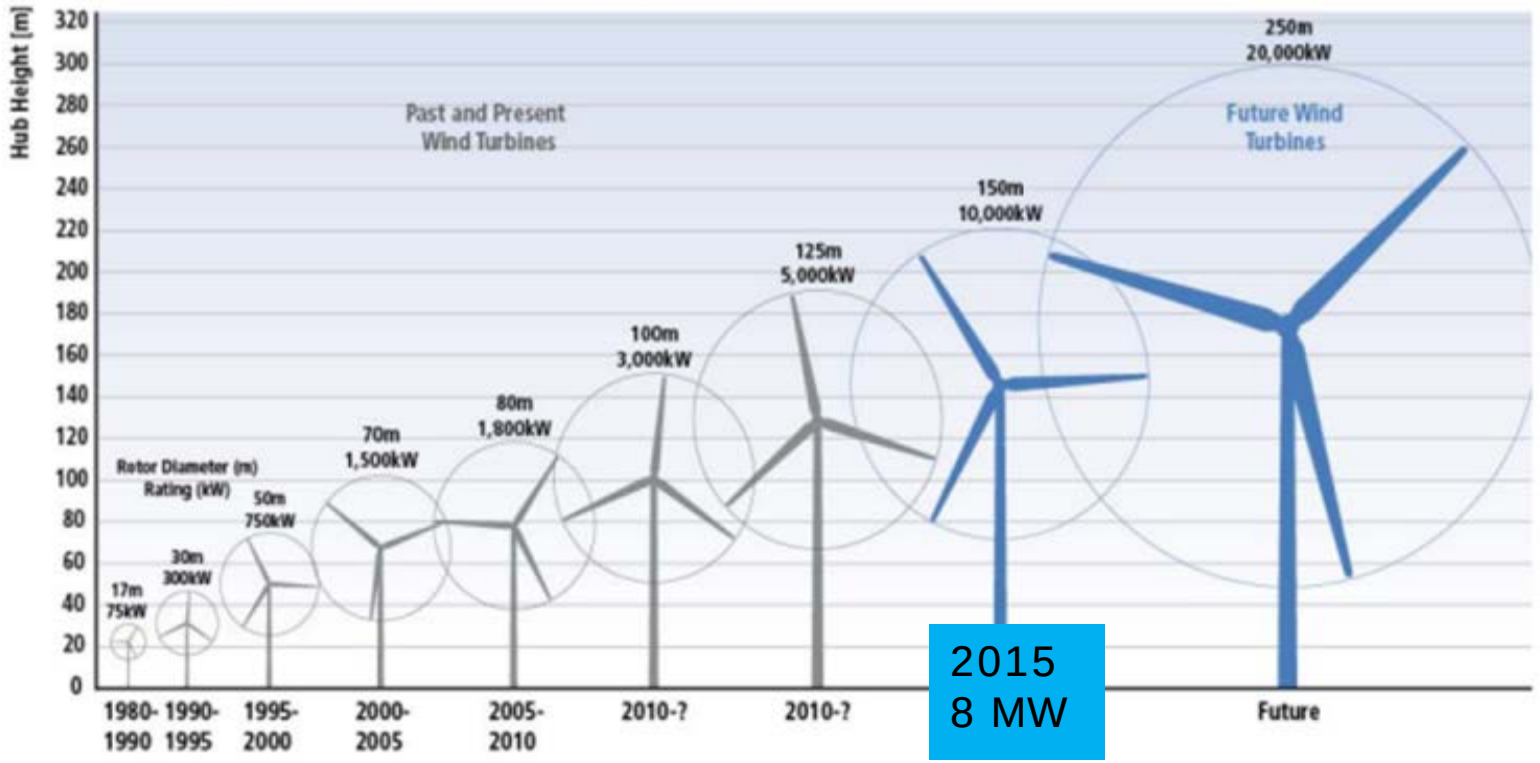
NEWA consists of 30 partners from 8 different European countries
DTU is coordinator

DTU Wind Energy

Test and Measurements

Wind Energy – Test and measurements

DTU Wind Energy testing of large wind turbines



(from the IPCC April 2012 report on mitigating climate change)

International wind turbine standards - IEC

a) Safety & functional requirements

↓

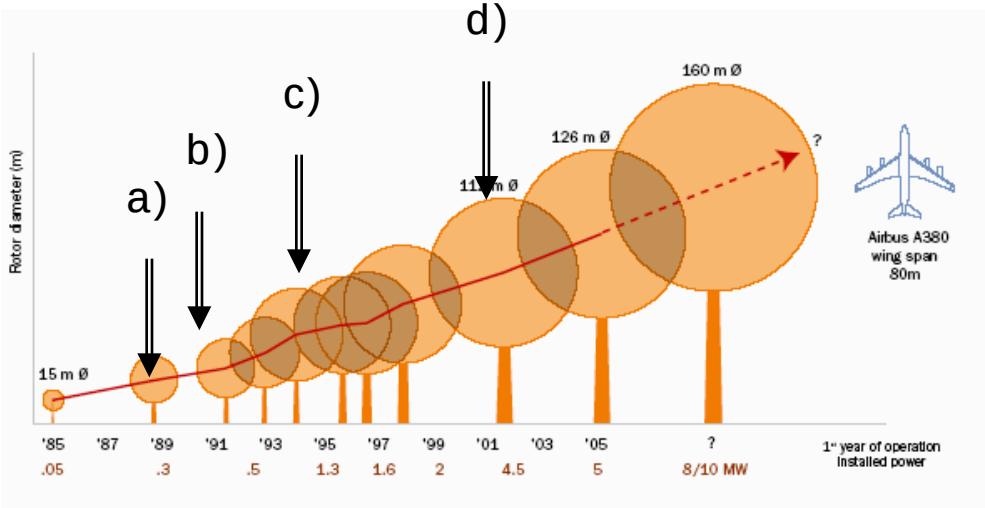
b) Test methods

↓

c) Certification procedures

↓

d) Interfaces & Component



IEC TC88: IEC 61400 series:

IEC 61400-1 Design requirements
IEC 61400-2 Small wind turbines
IEC 61400-3 Design requirements for offshore wind turbines
IEC 61400-4 Gears for wind turbines
IEC 61400-(5) Wind Turbine Rotor Blades
IEC 61400-11, Acoustic noise measurement techniques
IEC 61400-12-1 Power performance measurements
IEC 61400-13 Measurement of mechanical loads
IEC 61400-14 Declaration of sound power level and tonality
IEC 61400-21 Measurement of power quality characteristics
IEC 61400-22 Conformity Testing and Certification of wind turbines
IEC 61400-23 TR Full scale structural blade testing
IEC 61400-24 TR Lightning protection
IEC 61400-25-(1-6) Communication
IEC 61400-26 TS Availability
IEC 61400-27 Electrical simulation models for wind power generation

Wind Energy Worldwide

Top 12 countries by total wind installations

Position 2013	Country/Region	Total capacity end 2014 ** [MW]	Added capacity 2014 *** [MW]	Growth rate 2014 [%]
1	China	114'763	23'350,0	25,7
2	USA	65'879	4'854,0	7,8
3	Germany	40'468	5'808,0	16,8
4	Spain	22'987	27,5	0,1
5	India	22'465	2'315,1	11,5
6	United Kingdom	11'998	1'467,0	13,9
7	Canada	9'694	1'871,0	25,9
8	France	9'296	1'042,0	12,6
9	Italy	8'663	107,5	1,3
10	Brazil	6'182	2'783,0	81,9
11	Sweden	5'425	1'050,0	21,4
12	Denmark *	4'850	78,0	1,6
	Rest of the World	47'300	7'000 (estimated)	16,0
	Total	**370'000**	**51'753**	**16,2**

* by november 2014
** Includes all installed wind capacity, connected and not-connected to the grid.
*** Includes the net capacity addded during the year 2014.

Wind power share of electricity consumption

Denmark
Denmark set a new world record by reaching a wind power share of ***39%*** in the domestic power supply.

EU
The wind power capacity installed by the end of 2014 would, in a normal wind year, produce 284 TWh of electricity, enough to cover **10%** of the EU's electricity consumption.

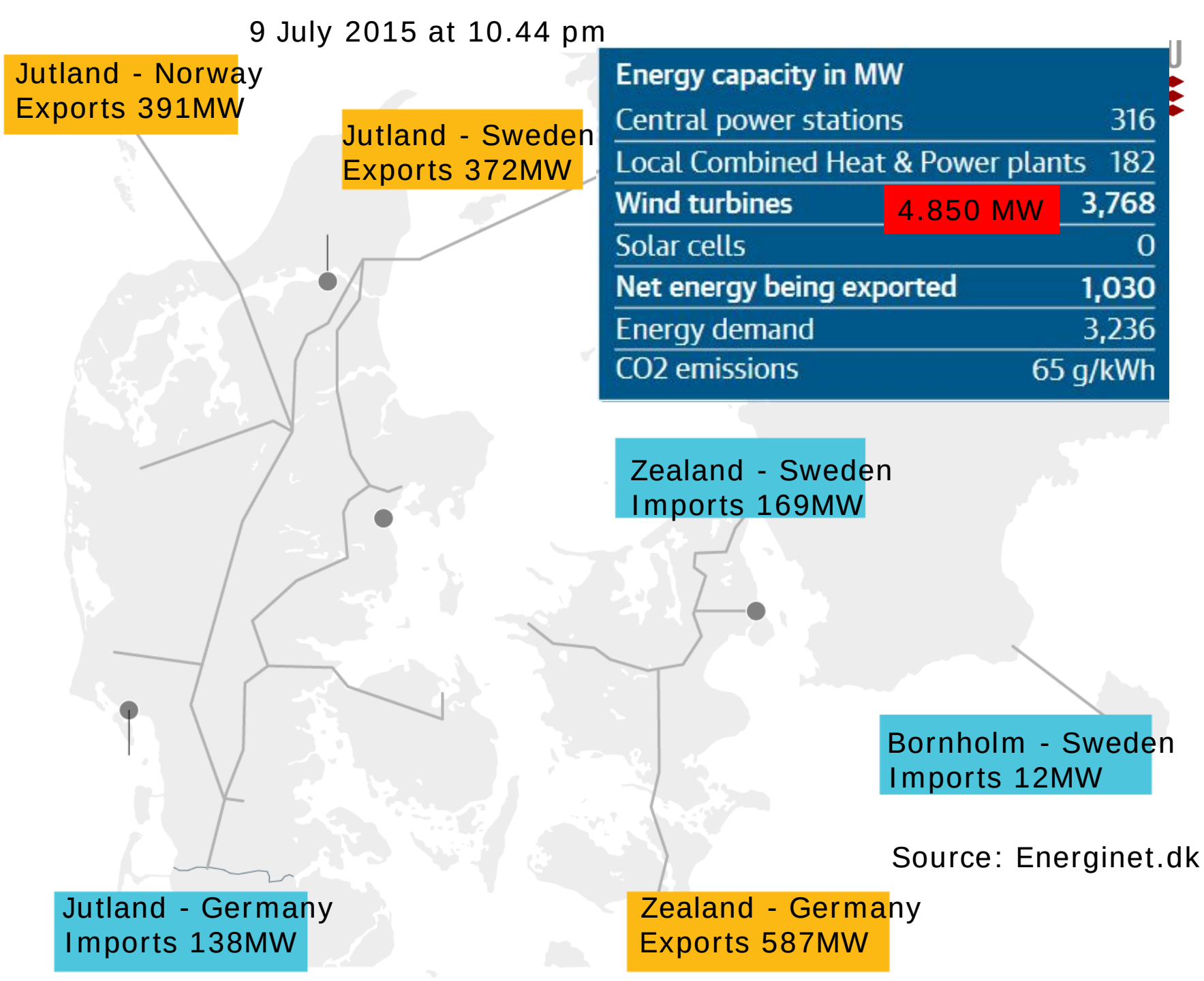
World
The wind power installed worldwide can now contribute close to **5%** of the global electricity demand.

Denmark exports wind energy on windy days

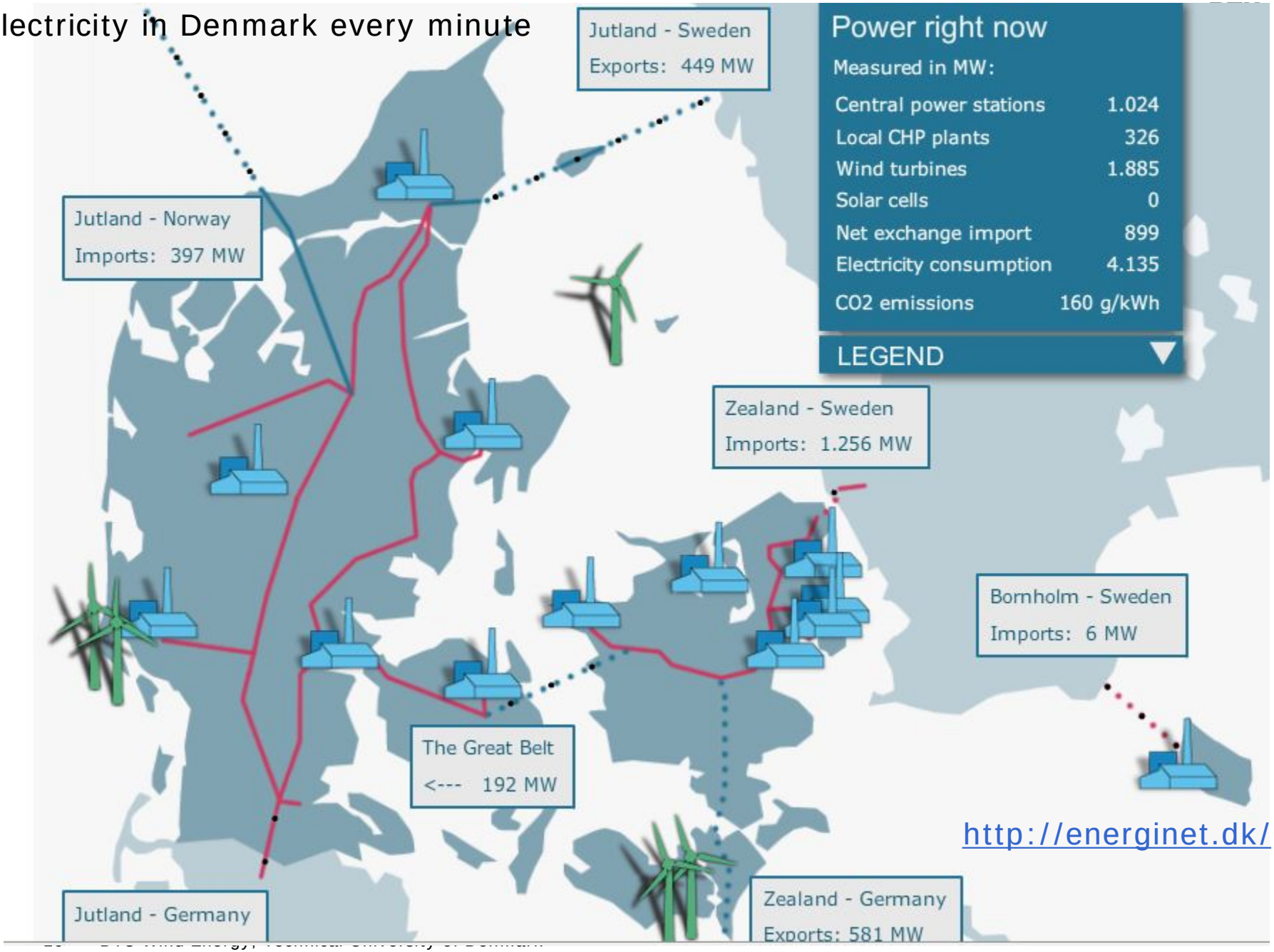
On an unusually windy day (9 July 2015), Denmark found itself producing 116% of its national electricity needs from wind turbines.

Later at night at 3 am, when electricity demand dropped, that figure had risen to 140%.

Interconnectors allowed 80% of the power surplus to be shared equally between Germany and Norway, which can store it in hydropower systems for use later. Sweden took the remaining fifth of excess power.


9 July 2015 at 10.44 pm
Jutland - Norway
Exports 391MW
Jutland - Sweden
Exports 372MW
Energy capacity in MW
Central power stations 316
Local Combined Heat & Power plants 182
Wind turbines 4.850 MW 3,768
Solar cells 0
Net energy being exported 1,030
Energy demand 3,236
CO2 emissions 65 g/kWh
Zealand - Sweden
Imports 169MW
Bornholm - Sweden
Imports 12MW
Source: Energinet.dk
Jutland - Germany
Imports 138MW
Zealand - Germany
Exports 587MW

Electricity in Denmark every minute



http://energinet.dk/

Denmark is first mover in wind energy

Denmark was the first country to install wind turbines more than 30 years ago and has been first mover in the wind industry for decades.

By 2020, wind power will account for 50% of the electricity supply, according to recent government targets.

Denmark is a global hub for wind power innovation and development.

The Danish wind industry encompass more than 350 companies and employs 25.000 people.

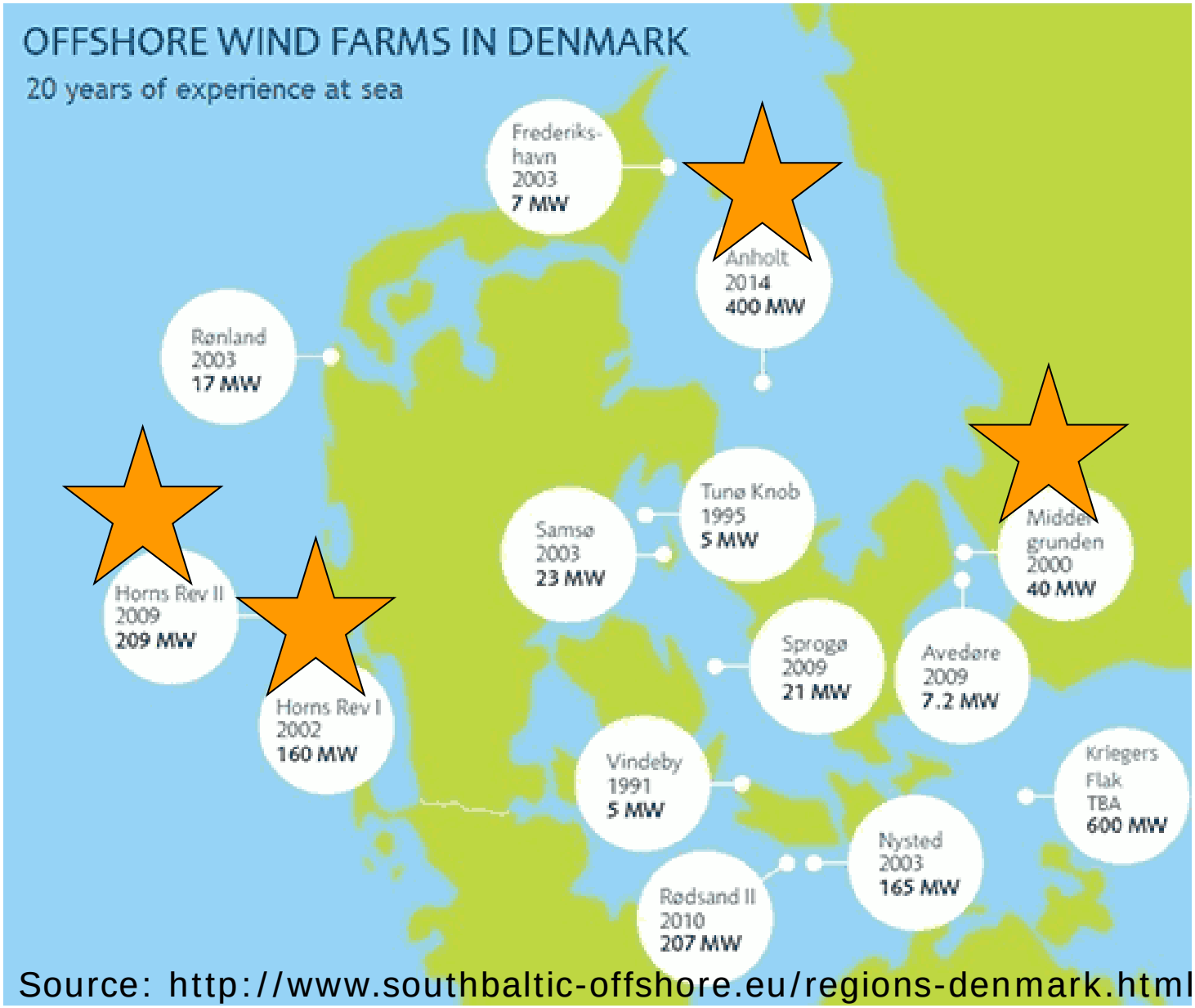
Denmark wind energy industry

- Vestas has installed more than 55.000 turbines and achieved 70 GW of installed capacity in 74 countries.
- Vestas wind turbines cumulatively can produce enough power to cover the annual electricity consumption of about 75 million European residential electricity consumers.
- It is estimated that 90 per cent of the world's **offshore** wind turbines are either Danish produced or have Danish developed foundations and components. (dominated by Siemens Wind Power wind turbines)

Wind power plans in Denmark

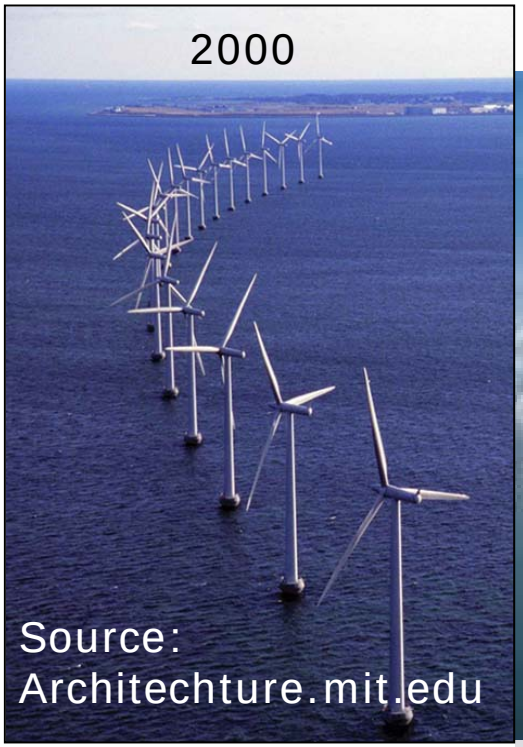
Plan for 50% wind power of annual electricity consumption by 2020.

Around ***0.5GW onshore*** and ***1.5GW offshore*** windfarms.

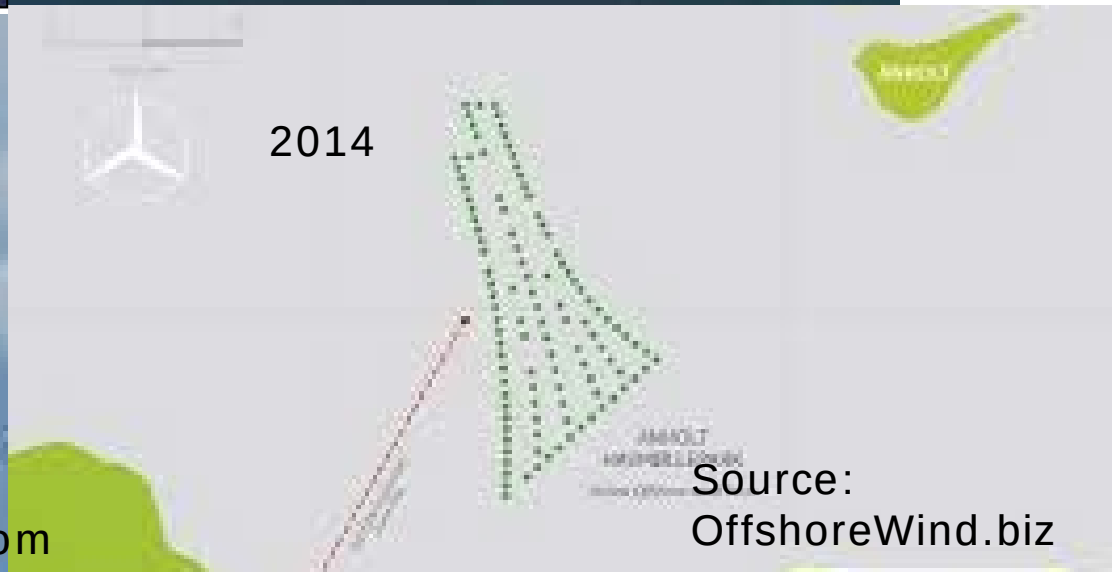


Source: http://www.southbaltic-offshore.eu/regions-denmark.html

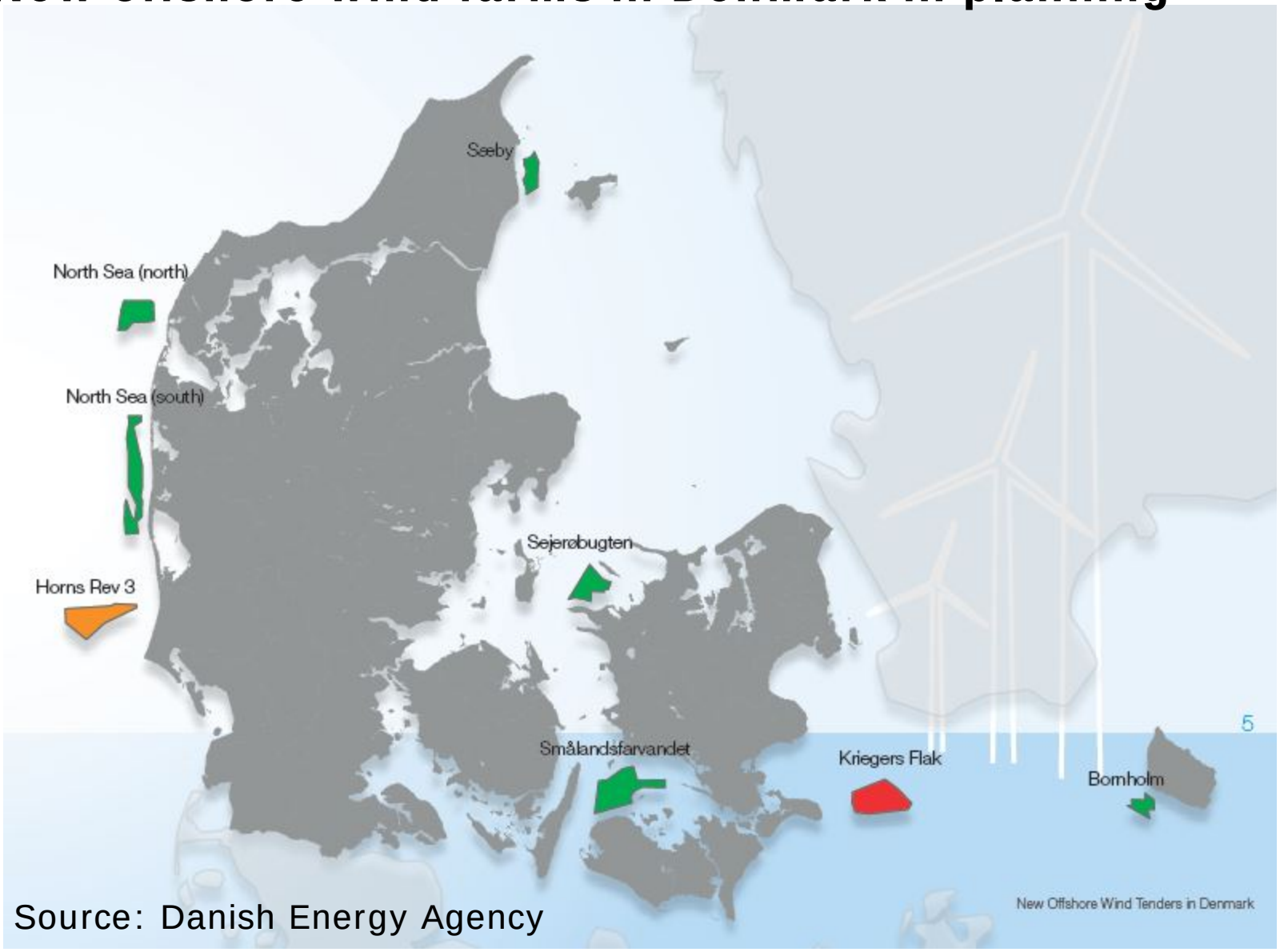
Danish offshore wind farm lay-outs



Source: mywindpowersystem.com



New offshore wind farms in Denmark in planning



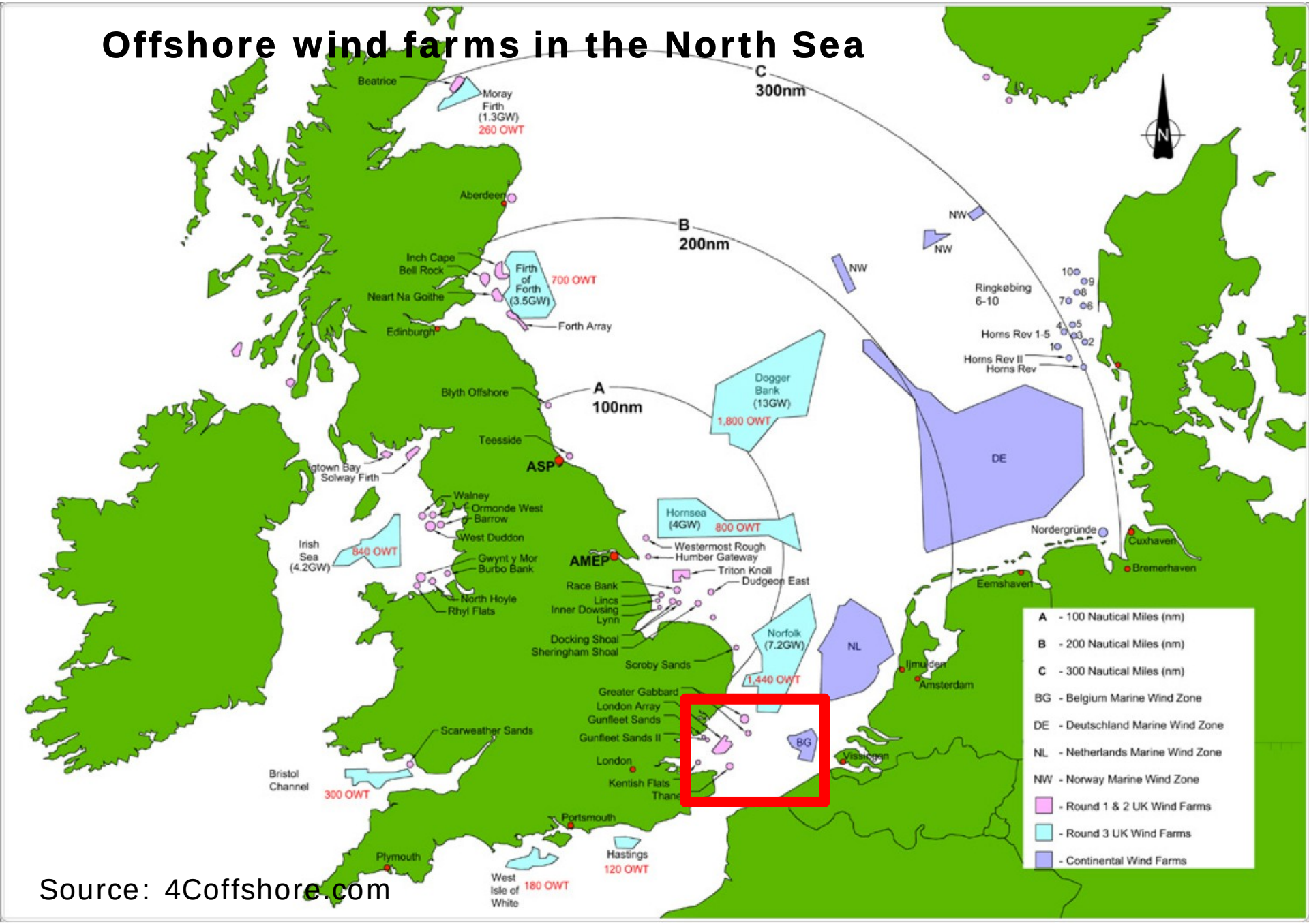
Source: Danish Energy Agency

Offshore **wind energy statistics in Europe**

- 3,072 offshore turbines are by end of July 2015 installed and grid connected, making a cumulative total of ***10 GW*** in Europe.

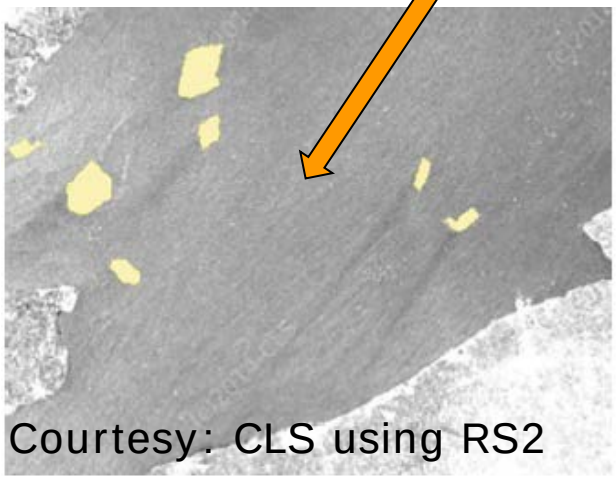
- Currently 15 commercial wind farms are under construction. Once completed, these wind farms will have a total capacity of over ***4 GW***.

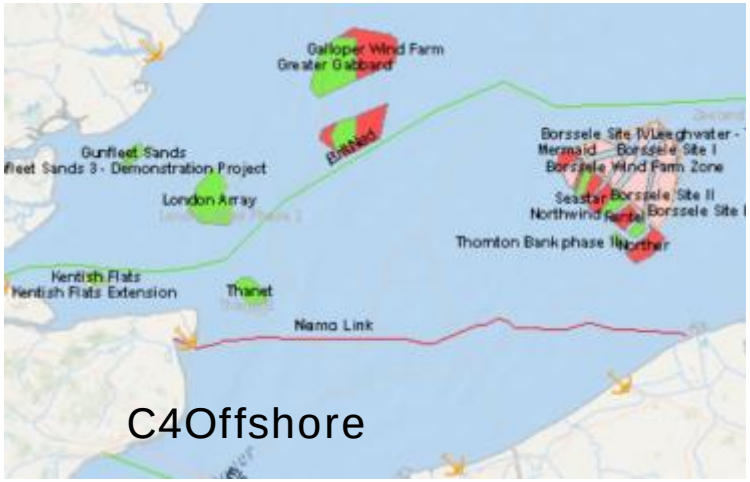
Offshore wind farms in the North Sea

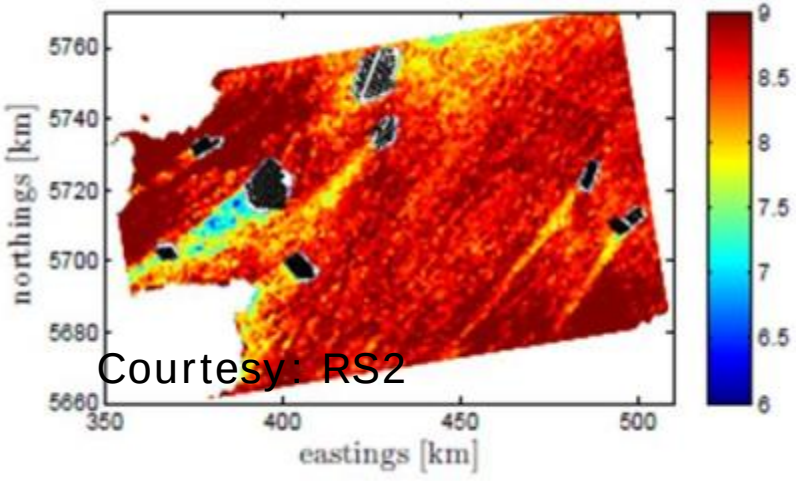


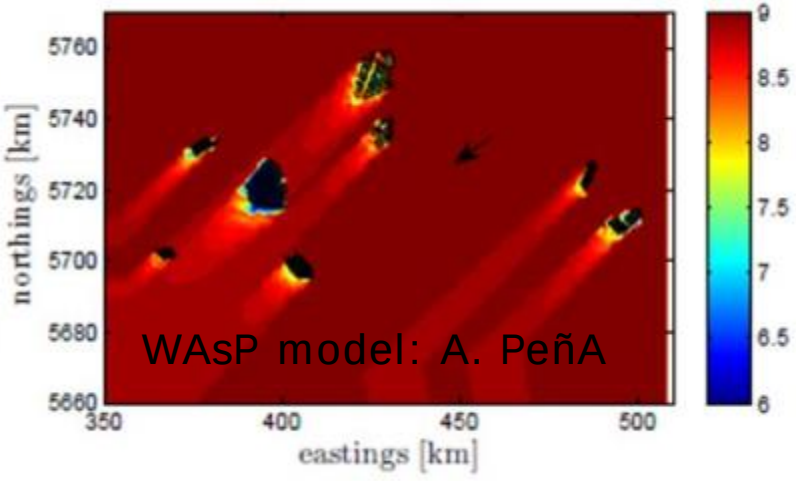
Source: 4Coffshore.com

Offshore wind farm wake: satellite and wake model

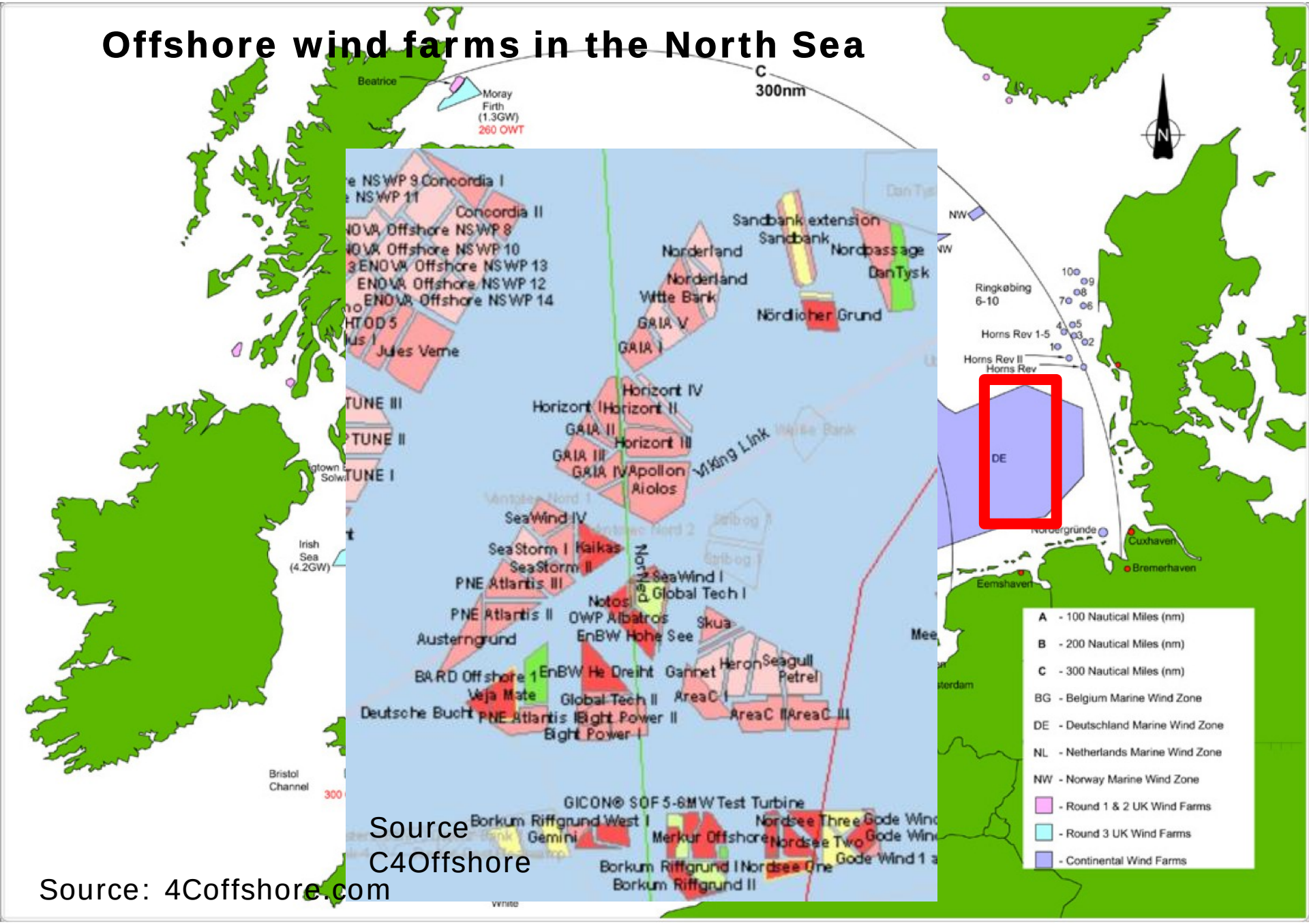








Offshore wind farms in the North Sea



Source C4Offshore

Source: 4Coffshore.com

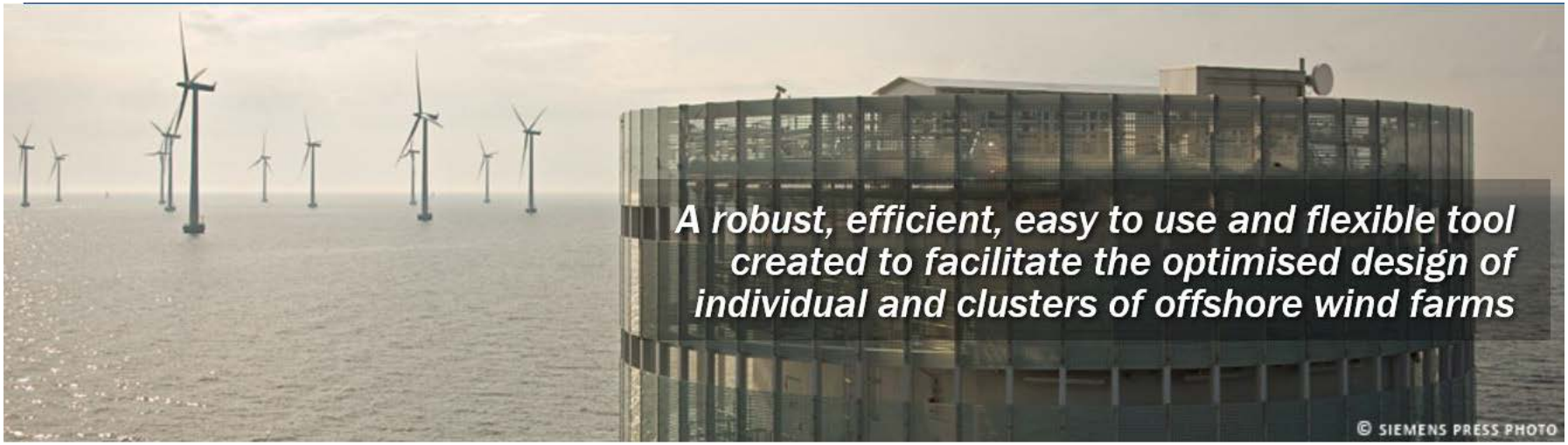
EERA –DTOC cost optimized farm design

Charlotte Bay Hasager, Peter Hauge Madsen, Gregor Giebel

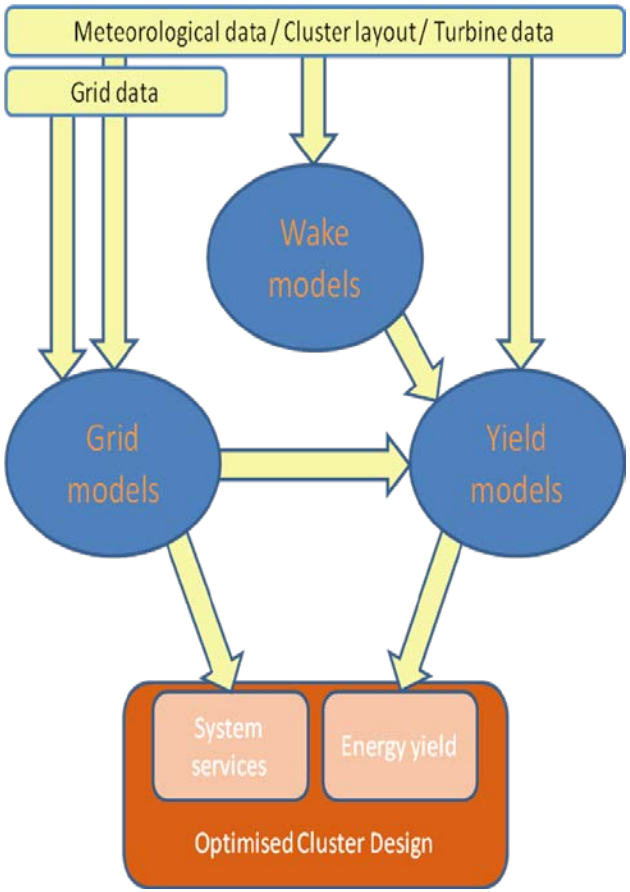
EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

Support by

Design tool for offshore wind farm clusters (DTOC)
Project vision



Concept and implementation



DTOC Tool

- GIS
- LCOE
- uncertainty
- FUGA
- WAsP
- WRF
- WRF/ROMS
- CorWind

DTOC Services

- eefarm
- FarmFlow
- WCMS
- Net-op
- SKIRON
- VENTOS

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Invitation from KIER to the ISES Solar World Congress 2015
Funding: EERA DTOC (No FP7-ENERGY-2011-1/n° 282797)
Funding: Global wind atlas (GWA)
Funding: New European Wind Atlas (NEWA)
Radarsat image: MacDonald, Dettwiler and Associates Ltd.